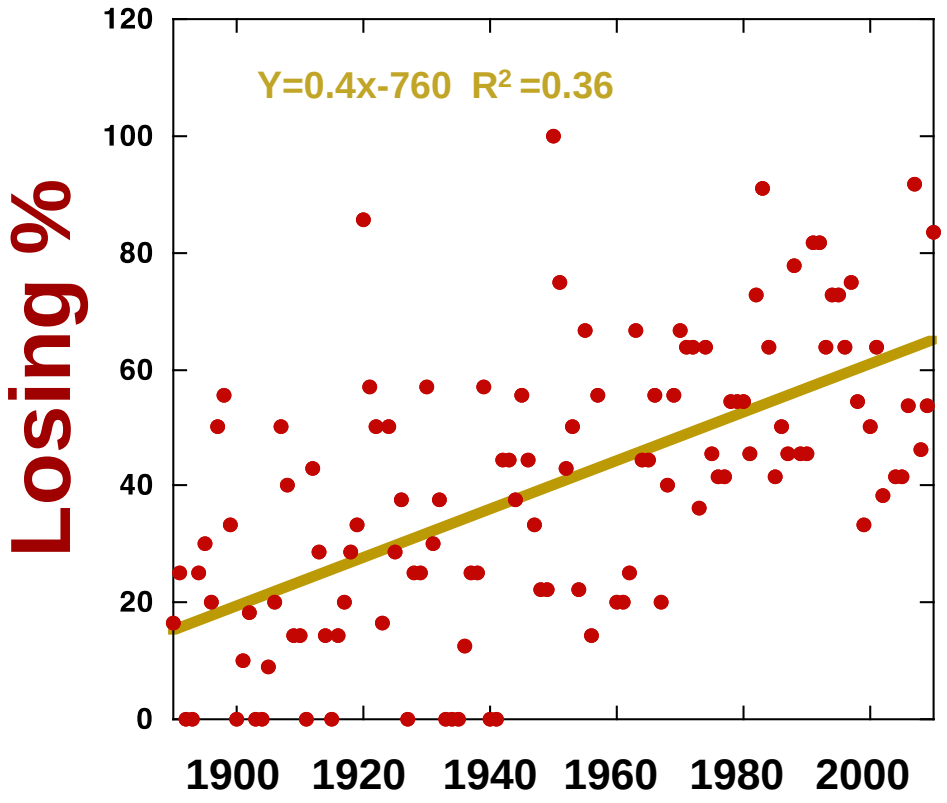
Suspended Sediment and Flow: Understanding Change Over Time

Golden Gopher Football



Flow like Football..

- Is there a significant change
- Why does it change
- **Real vs Speculation**

Suspended Sediment and River Flow Change over Time: Evaluating Reality

"8 Goths and 22 Norwegians on exploration journey from Vinland over the west... We were and fished one day. After we came home, 10 men red with blood and tortured. Hail Virgin Mary, save from evil. Have 10 men by the sea to look after our ship, 14 day - journeys from this island year 1362."

Shawn Schottler[1], Jason Ulrich[2], Dan Engstorm[1], Rick Moore[3] Patrick Belmont[4]

1. St. Croix Watershed Research Station, 2. Univ. of Minnesota, 3. MN State Univ. Mankato 4. Utah State University

Support provided by: LCCMR:Minnesota Environment and Natural Resources Trust Fund
MN Pollution Control Agency, EPA Section 319 Grant

Kensington Runestone

Found 1898 by Olof Ohman
While removing stumps in a field
near Kensington Minnesota.

TSS, Flow and the Stone
Exercises in Evaluating Reality

Observation

Evidence

Interpretation

Response

Real or Not Real ?

Excess Suspended Sediment—
Turbidity a serious water quality impairment

Confluence of St. Croix and Mississippi Rivers
(80% of sediment load from Minnesota River)

Recc

Lake Pepin:
Natural Im
80% of Sec
MN- Rive

Washington County twincities.com

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MediaNews group LLC Wednesday, December 25, 2012 50 cents

Lake Pepin: Archive of MINN Erosion History

By Brad Pitt
pitt@pioneer.com

Lake blah blah blah, scientists blah blah blah, corn blah blah blah, sediment blah blah blah agriculture, He said blah blah an

She said. blah blah blah, scientists blah blah blah, corn blah blah blah, mud blah blah blah Minnesota, blah blah blah bl-ah. Everyone mad blah blah and then whamo blah blah blame blame blame no solution in sight, duh dho said homer

Cities farms aliens blah blah blah, blah blah blah, corn blah blah blah, sediment blah blah blah water water everywhere, blah blah blah bl-ah. He says blah blah natural environment blah blah, no end in sight. Stadium.

Rare lake serves as fortune teller of the past.

Chuck Norris named defender of unique riverine lake.

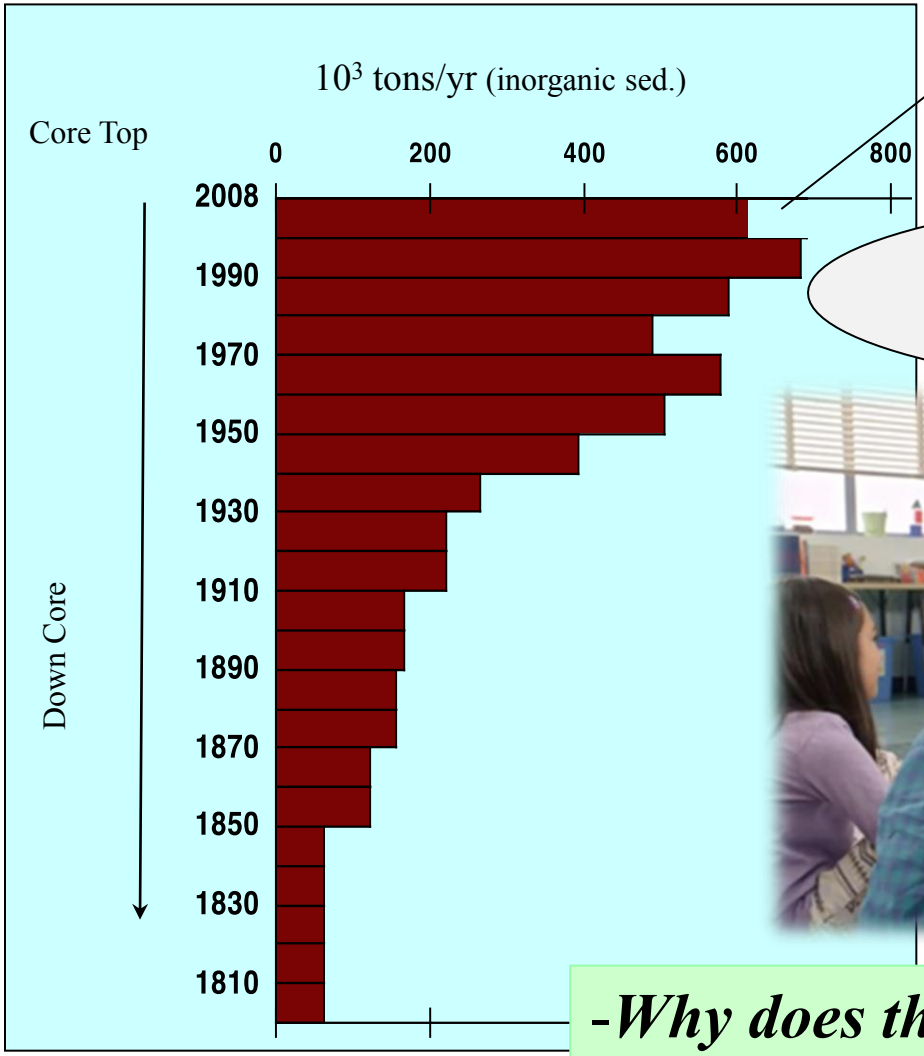
Applies for conceal-carry permit from Wisconsin

Cities farms aliens blah blah blah, blah blah blah blah, sediment water water everywhere, blah blah blah bl-ah. He says blah blah natural environment blah blah, no end in sight. Stadium.

ores
rates over time

Lake Pepin Sediment Accumulation History

We can't solve the problem until we understand what is causing the changes.



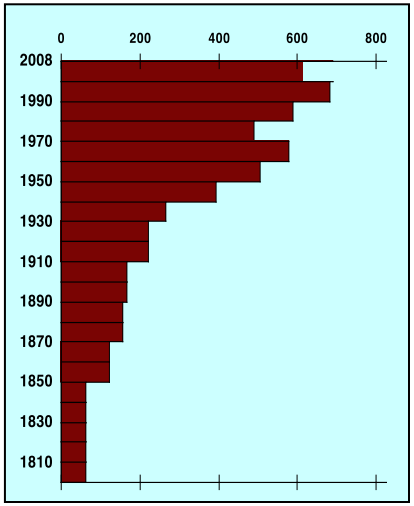
- 9X faster than pre-settlement
- Impaired for turbidity

What's the cause:
field erosion or streambanks

-Why does the rate change the way it does
- Do the sources also change?

What is the source of the sediment ?

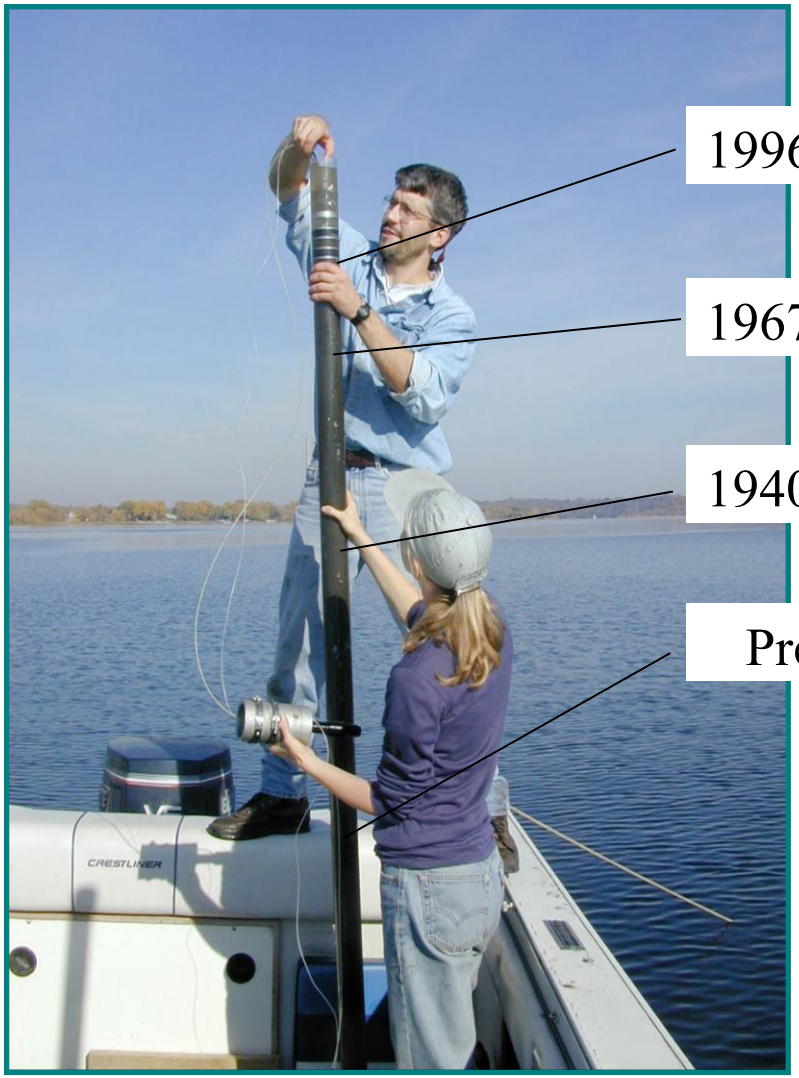
Lake Pepin Sediment Accumulation History



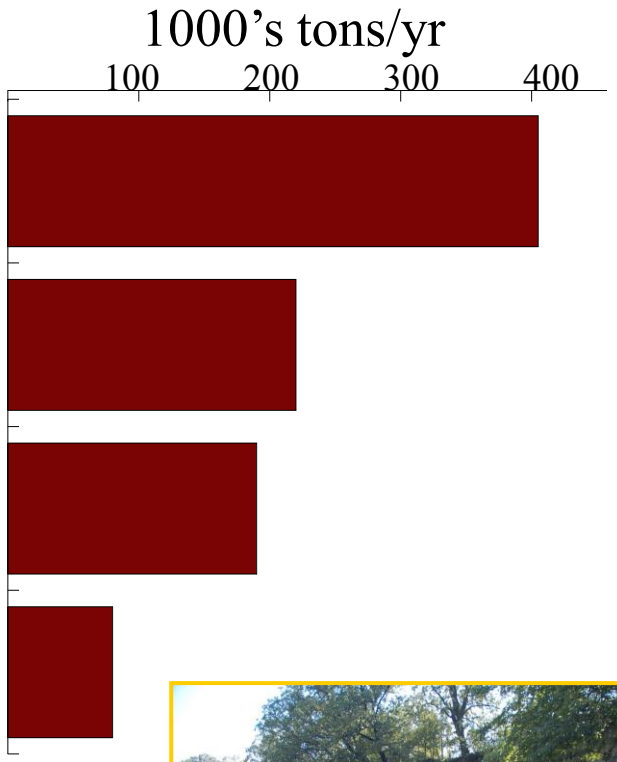
Field Erosion

Non-field

Lake Pepin Sediment Fingerprinting:



Sediment Eroded from Streambanks



Hmm…Have our rivers become more erosive … and why?

Natural sources are eroding at an un-natural rate

Why has Non-field Erosion Increased

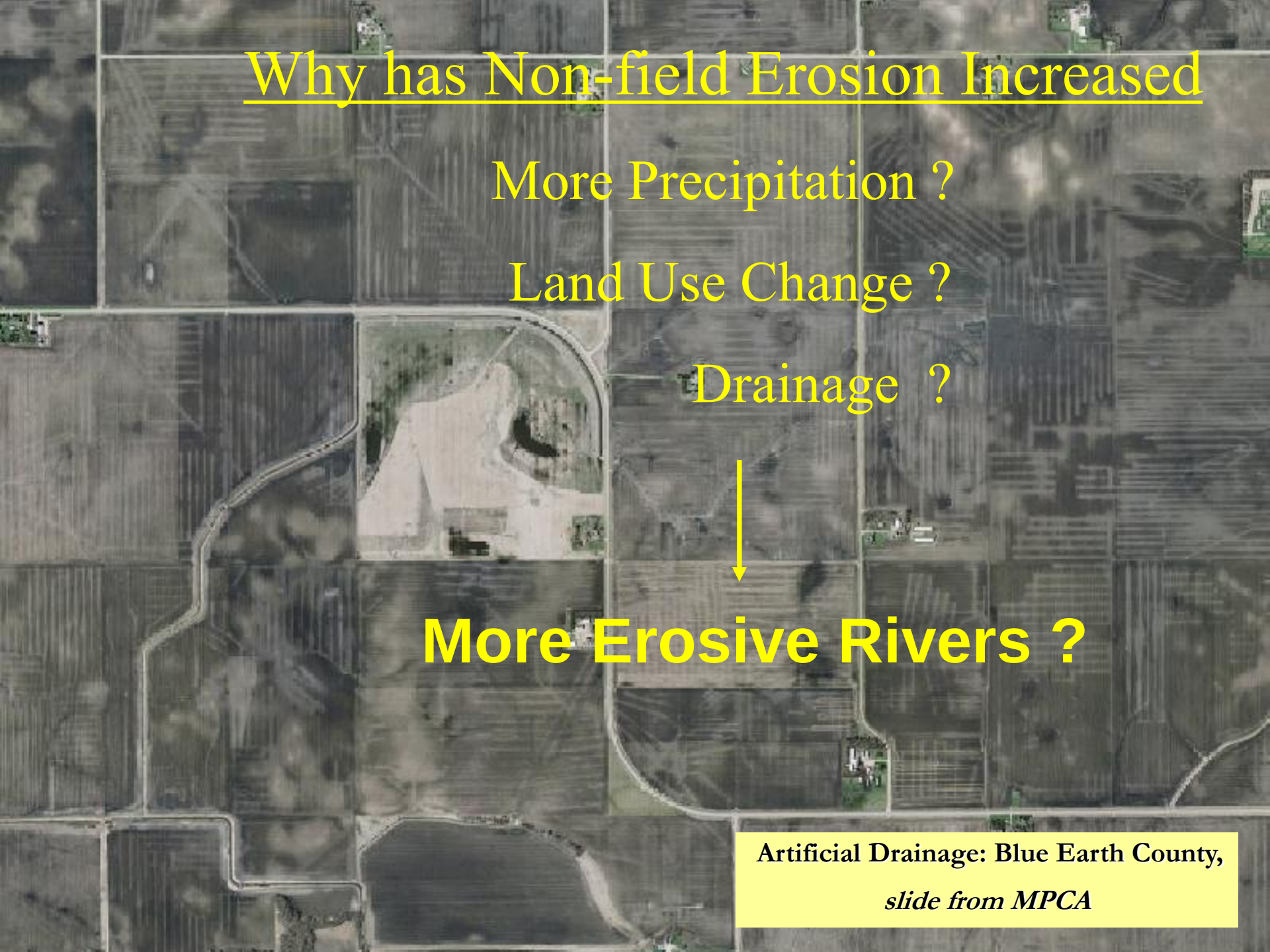
More Precipitation ?

Land Use Change ?

Drainage ?

↓

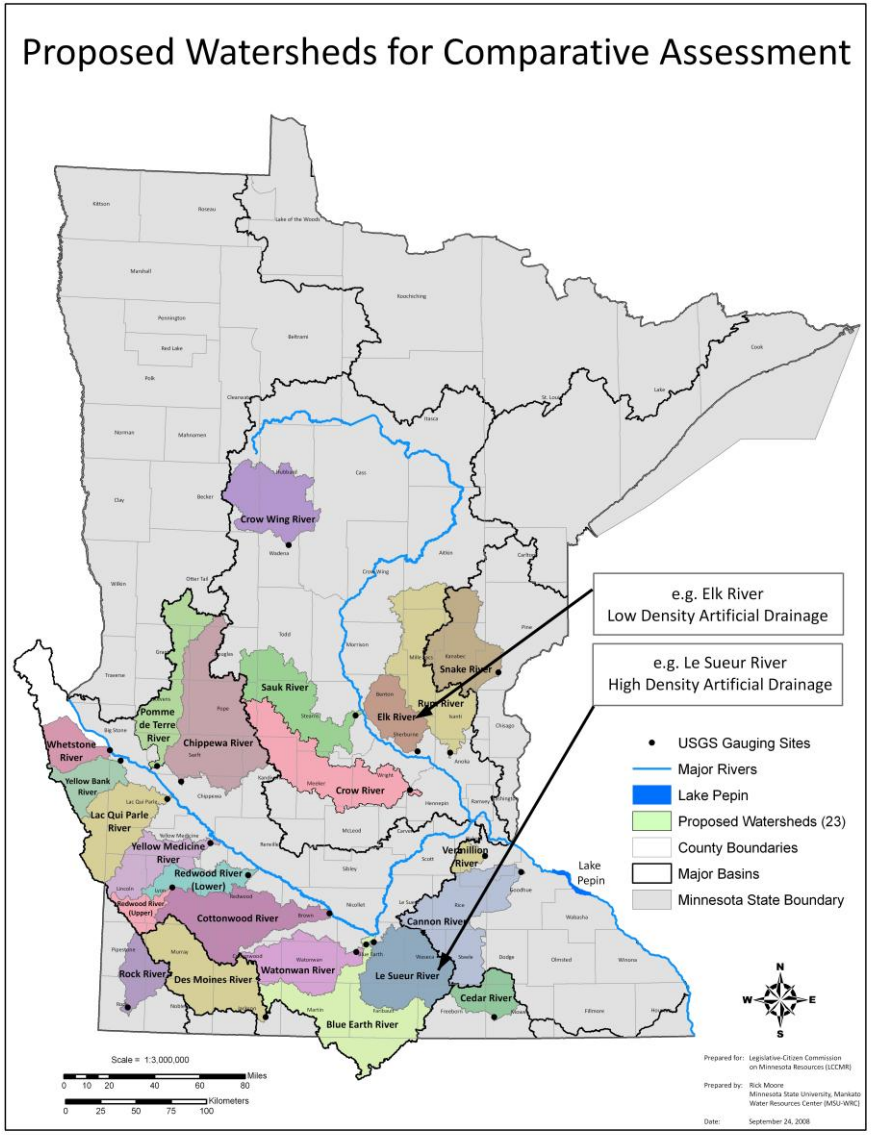
More Erosive Rivers ?



Artificial Drainage: Blue Earth County,

slide from MPCA

Changes in Hydrology:
Compare watersheds with Differences in Drainage & Crops



Hypothesis:

Have rivers become more erosive?

Test for Hydrologic Changes:

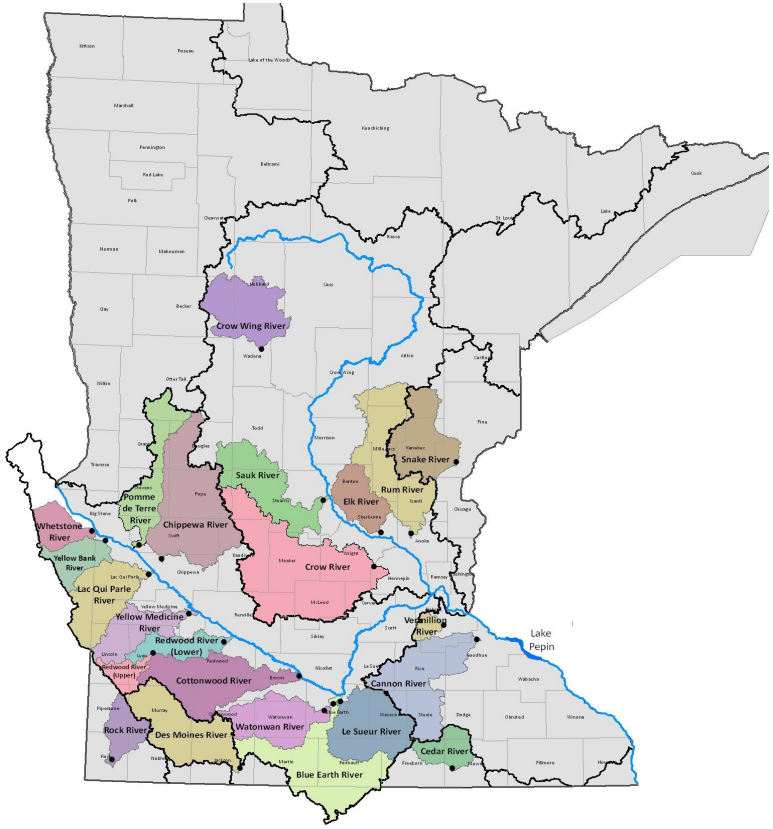
-over time

-between watersheds

-link to amount/density of drainage

-"normalize to climate"

River Flow



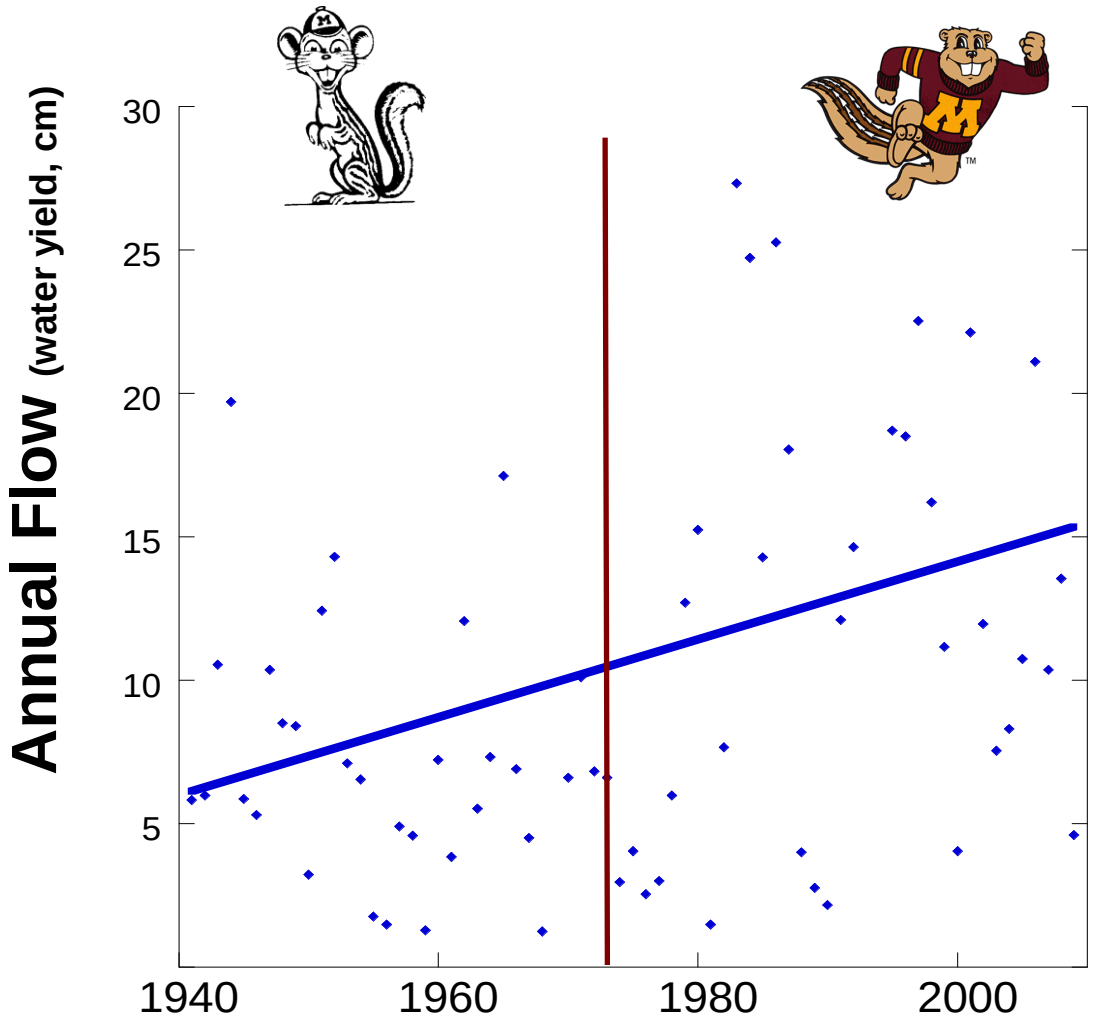
- **<u>Has flow increased ?</u>**

- **21 watersheds flow records 1940- 2009**

- **Compare Different Watersheds.**

Change in Flow

Cottonwood River



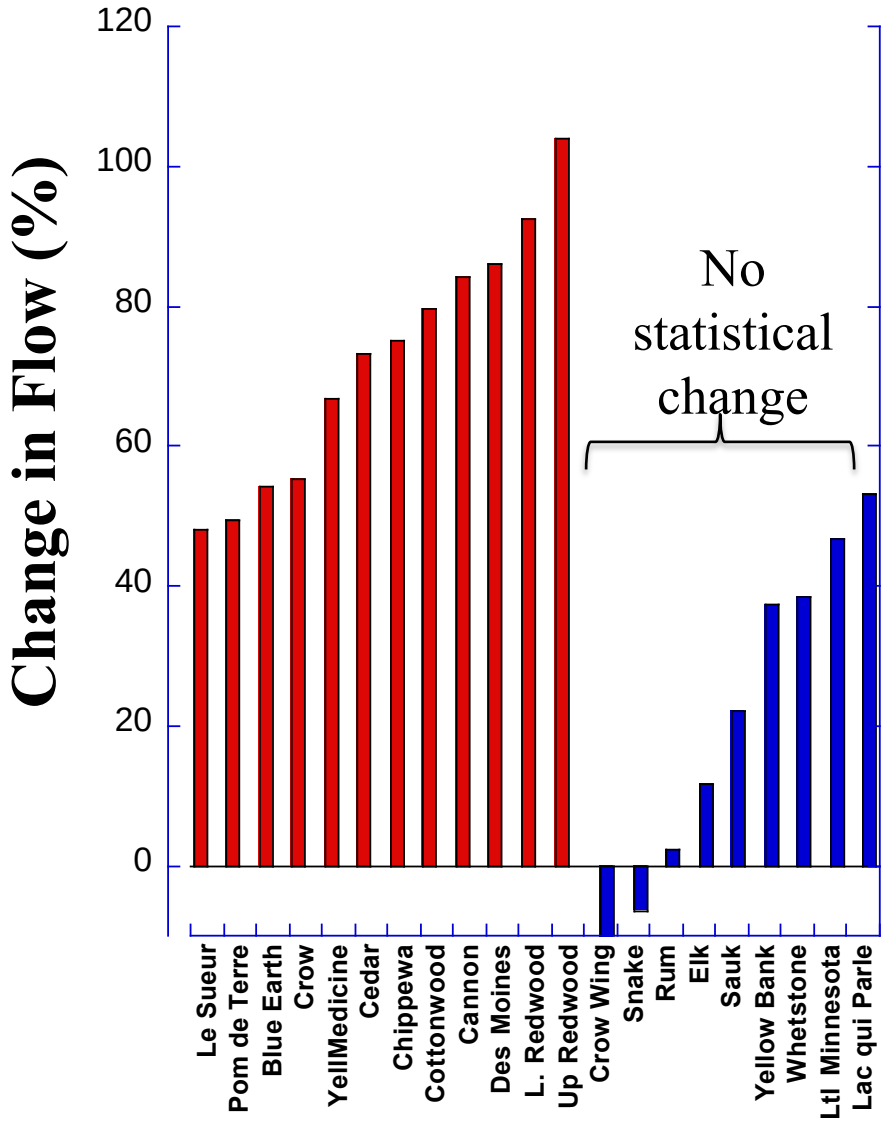
Increase <u>significant !</u>
Kendall tau p<0.05

1940 - 1975
Median = 7.8 cm

1976 - 2009
Median = 13.7 cm

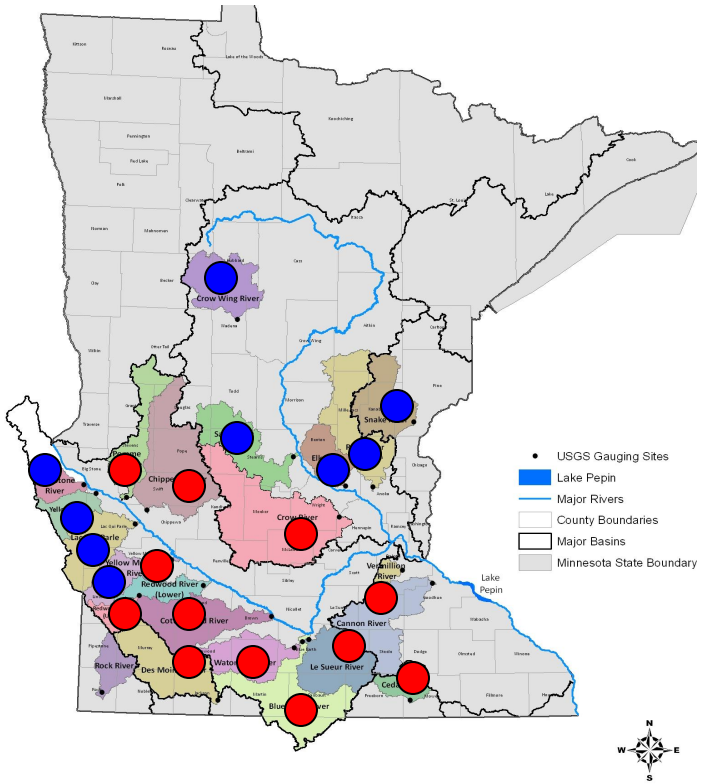
75% increase

Increase in Flow 1940-1975 vs 1976- 2009



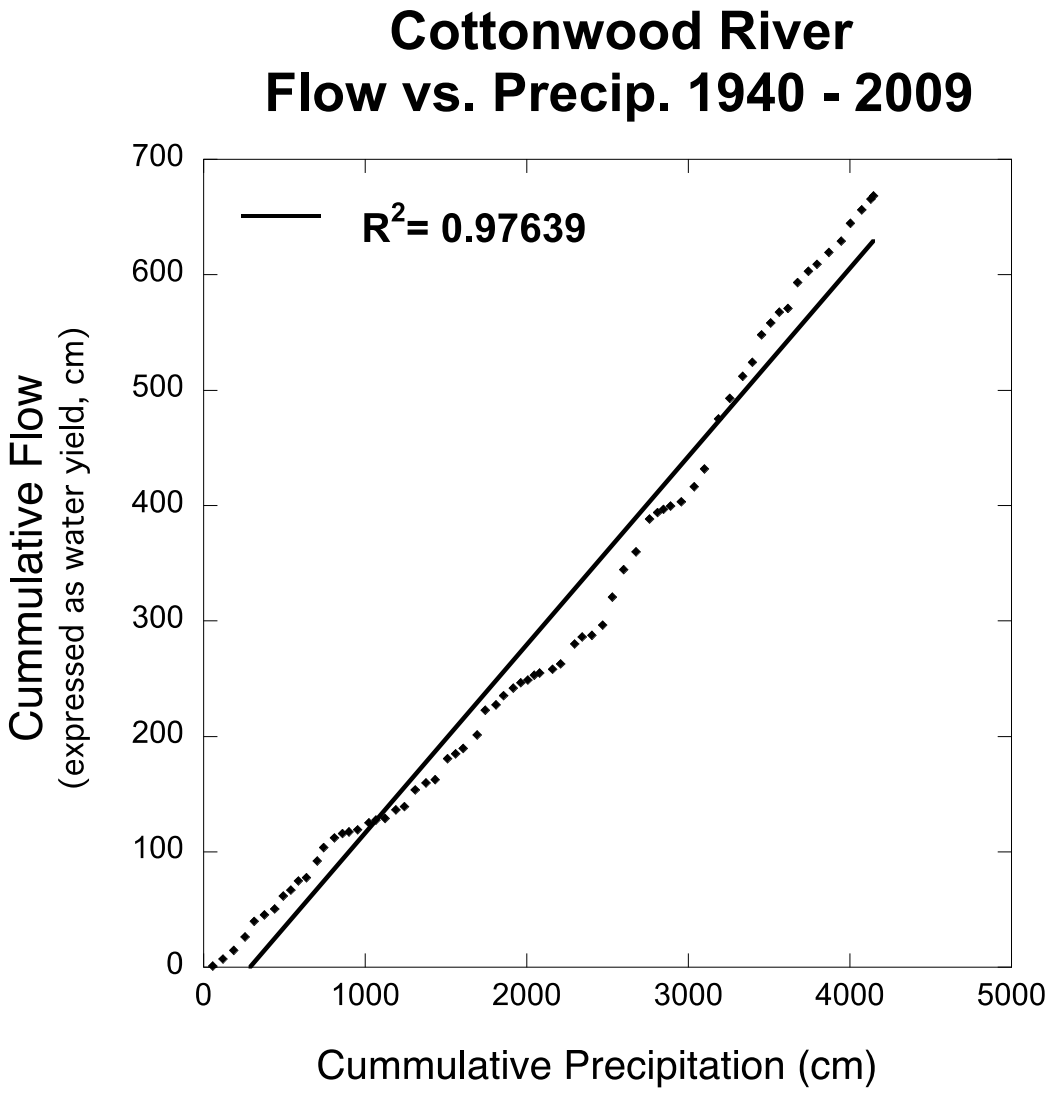
-Change is large,
40 - 100% increase

-Changes are not random



Is Rainfall the Driver of Flow ?

What if we simply plot flow as a function of Precip



- As Precip increase Flow increase

- Cumulative approach accounts for antecedent effects

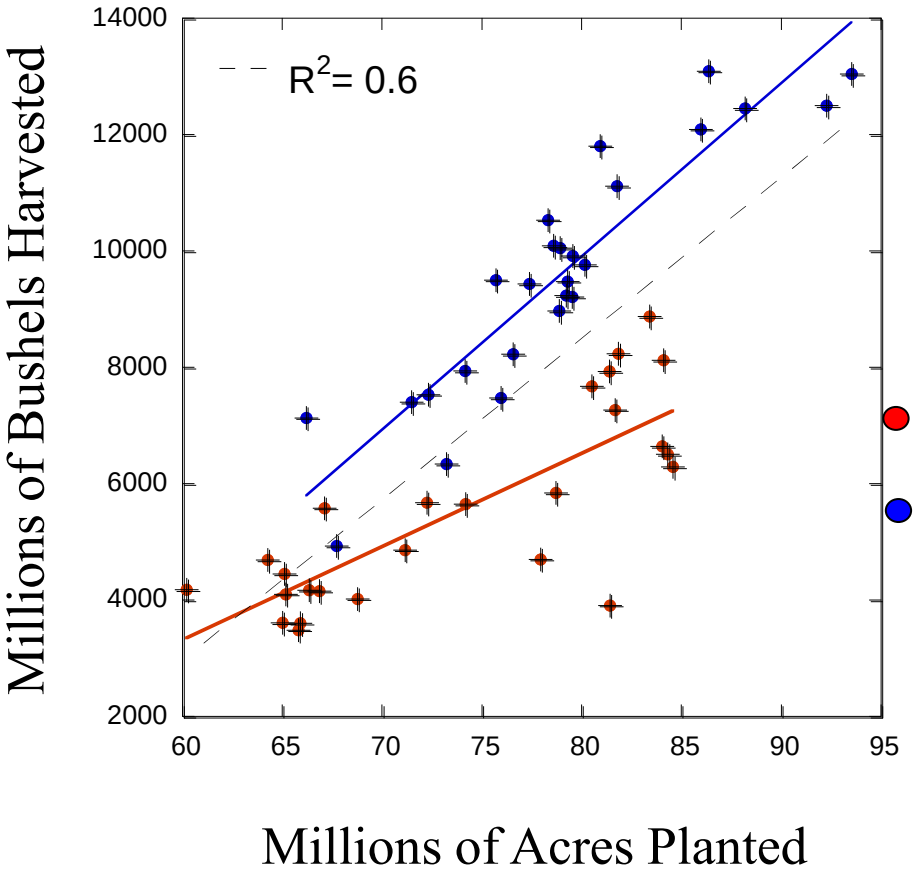
- Strong correlation

- Rainfall is driver of flow!

- Are we sure ?

Thinking about regressions…. an example

Corn Planted vs Harvested 1960-2010

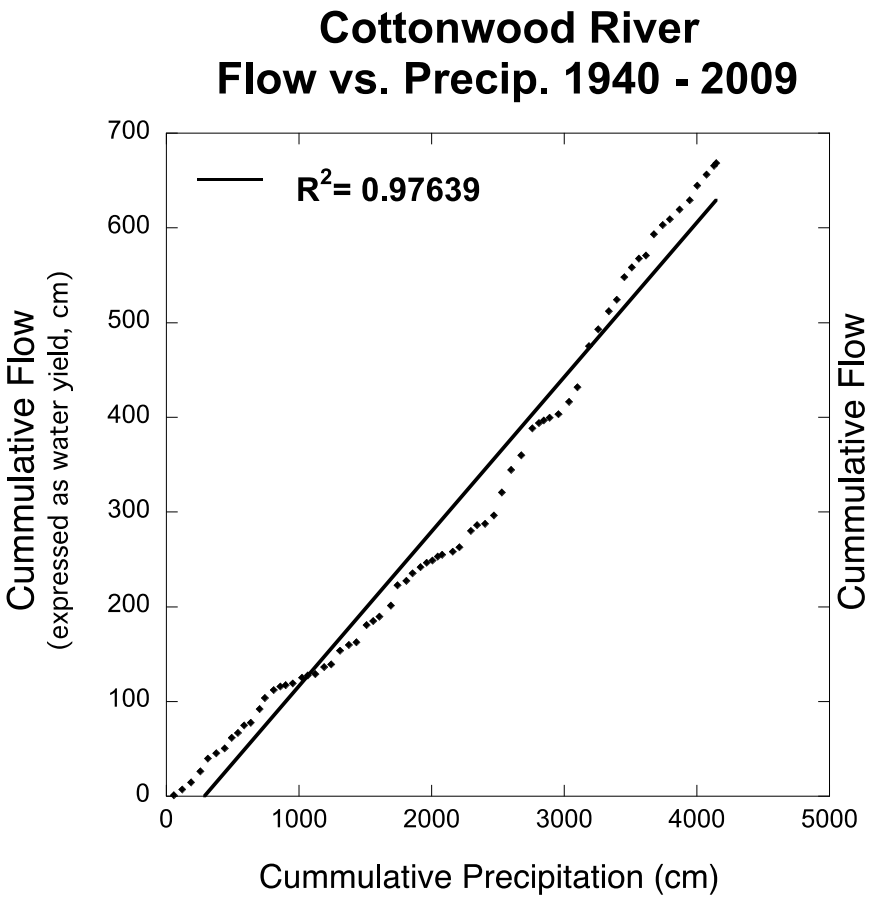


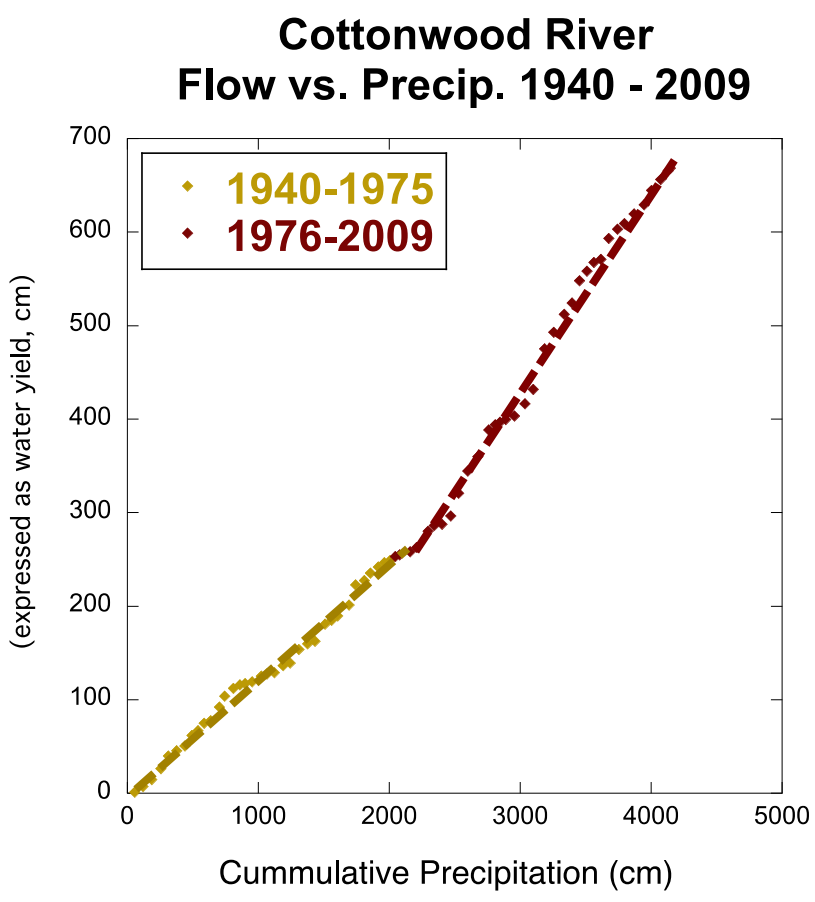
Plant more core = harvest more corn

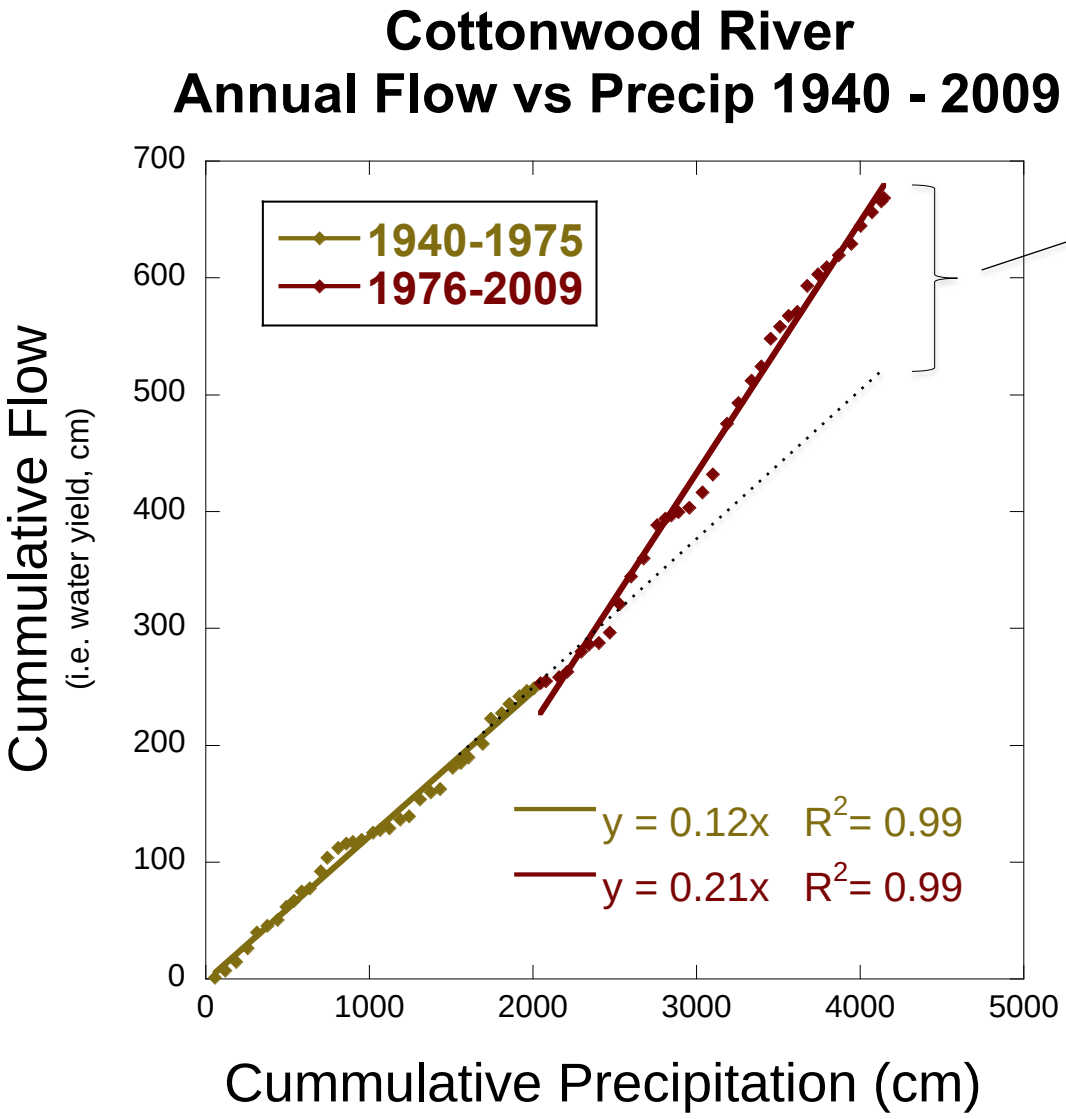
Relationship linear, therefore yield (bushels/acres)constant over time…

Apparent linear relationship is changing over time.

What if we separate this into different time periods



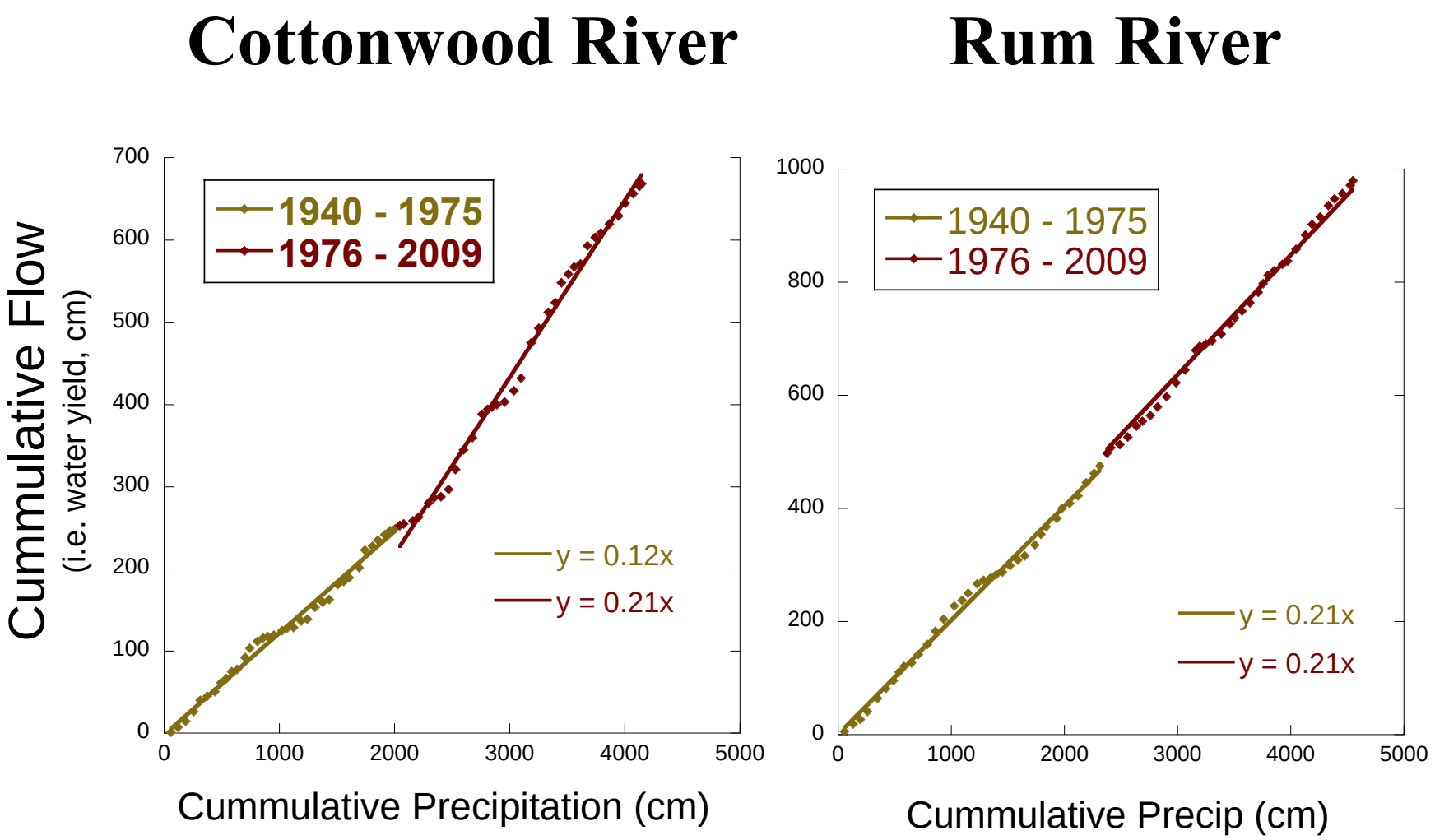




Increase in flow above and beyond increase due to increases in precip

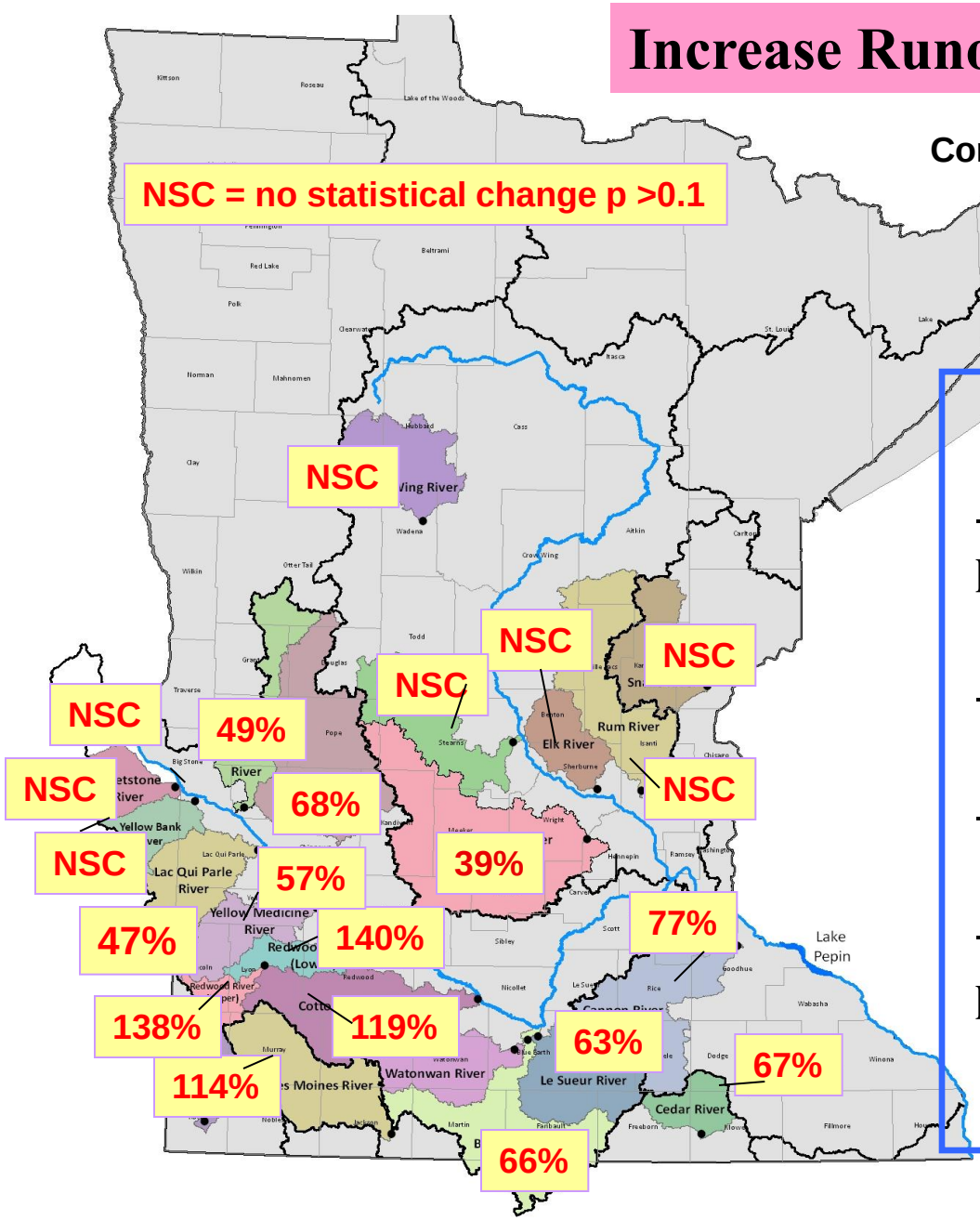
Precip is a driver of flow, but the relationship between flow and precip has clearly changed over time…why

Strategy: Comparison of 21 watersheds—why are they different



Increase Runoff Ratio (flow/rainfall)

Comparing 1940-1975 vs. 1976-2009



Change in Runoff Ratio

- Changes are significant & large.

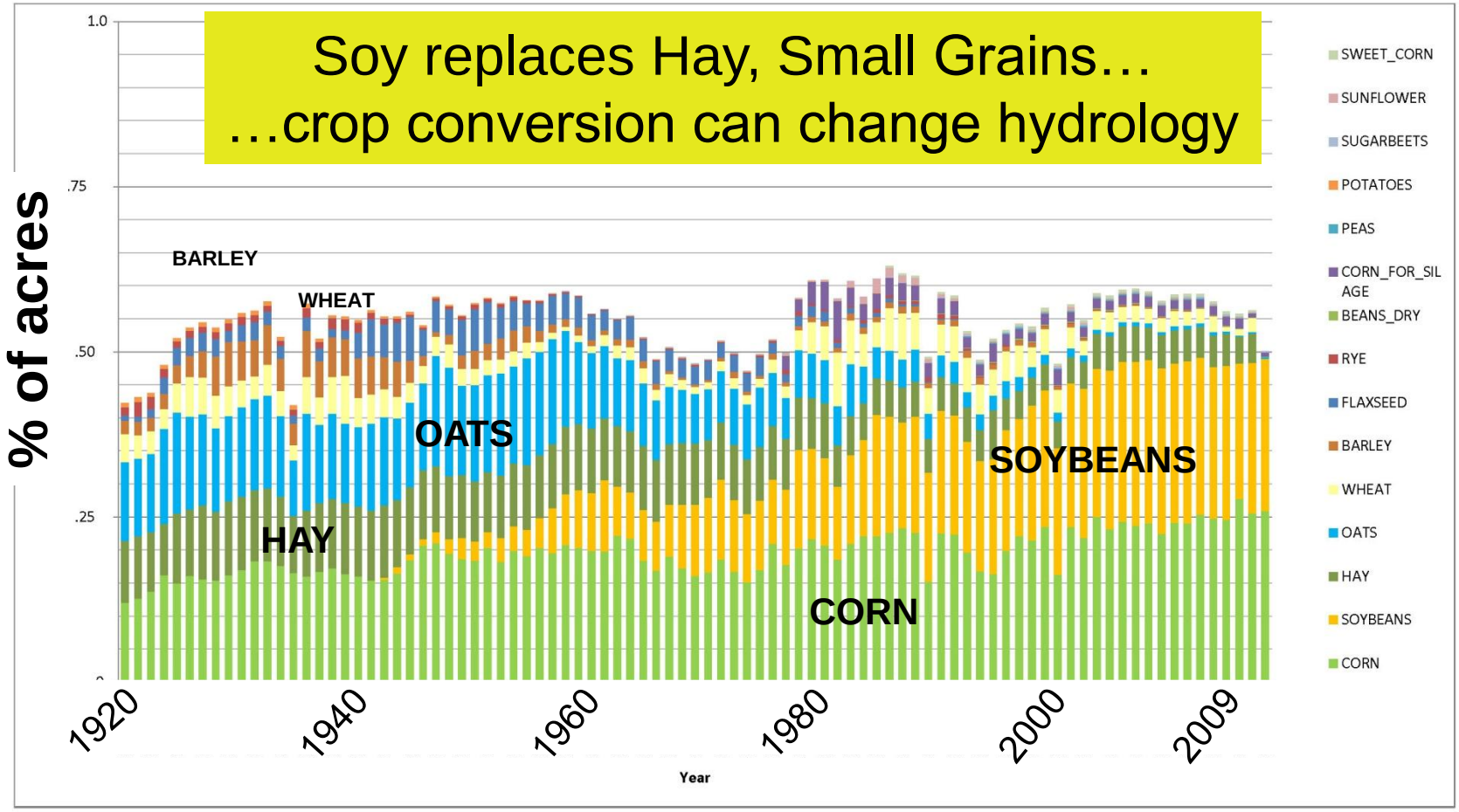
- Not all watersheds change

- Change is not random

-Change in flow NOT proportional to change in precip

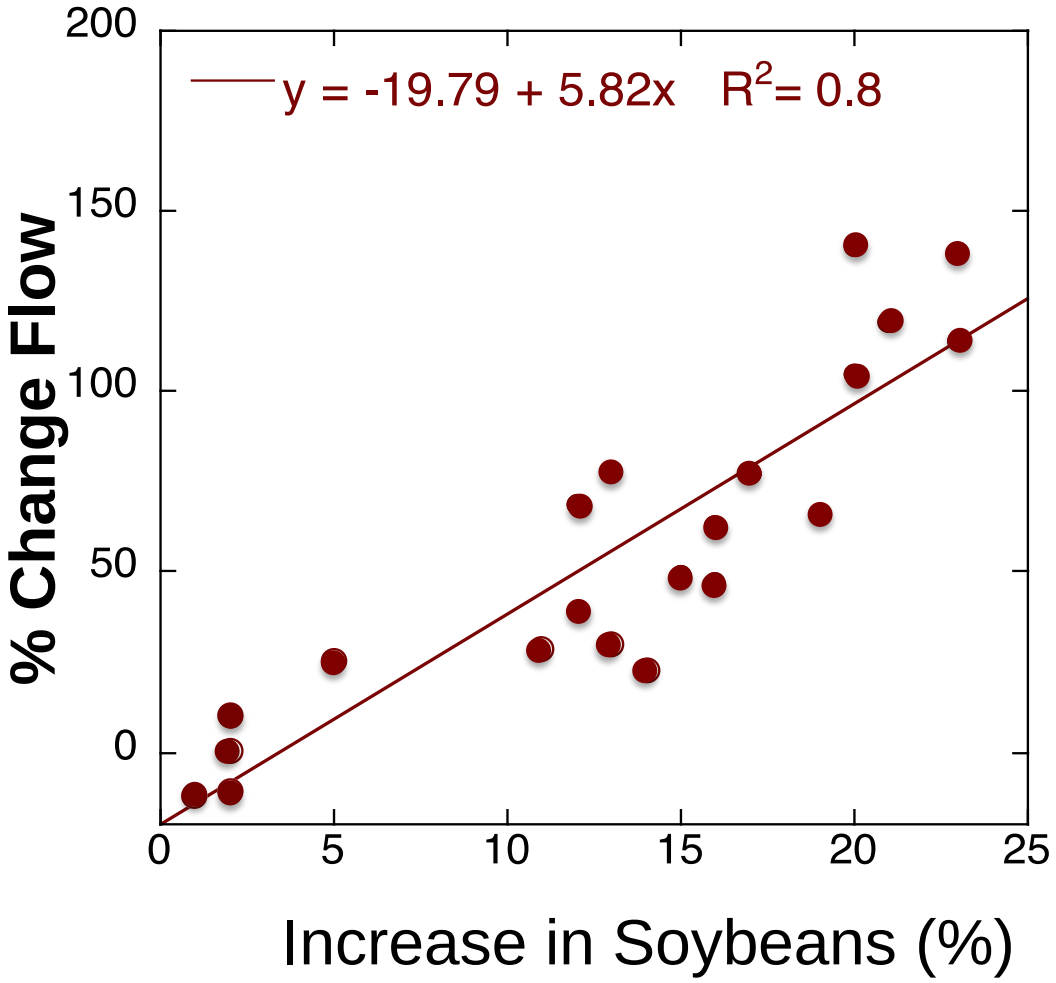
What else has changed?

Changing Crops



Data from Rick Moore, Mankato State, Water Resources Center

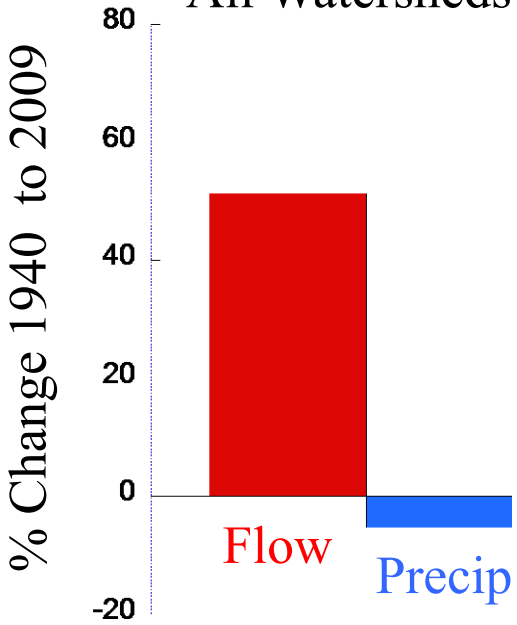
Change in Soy Acres and Flow for all 21 Watersheds



Seasonal Change

May-June

All Watersheds



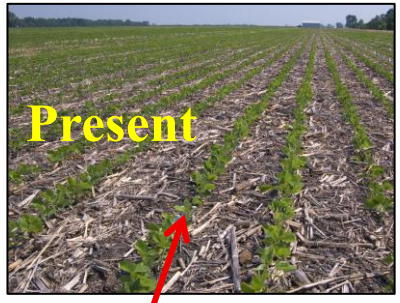
May-June

- Largest increase in flow
- No increase in rainfall *(increase is in autumn)*
- **40% of sediment load**

- Large Change in Plant Cover

Alfalfa field, May

Soy field, May



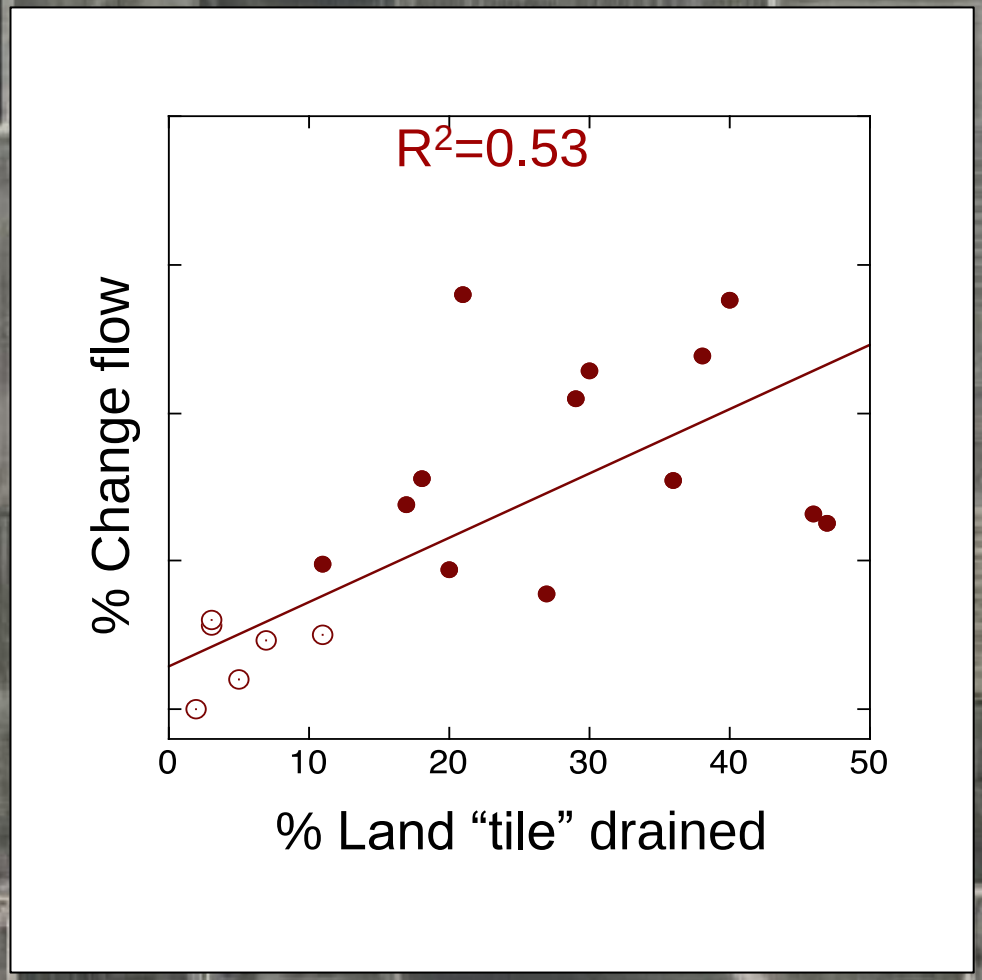
This uses more water than This

- 70% of alfalfa converted to soy

Flow increasing during time of year where water use by crops has decreased

What else has changed ?

Artificial drainage: "tiling"

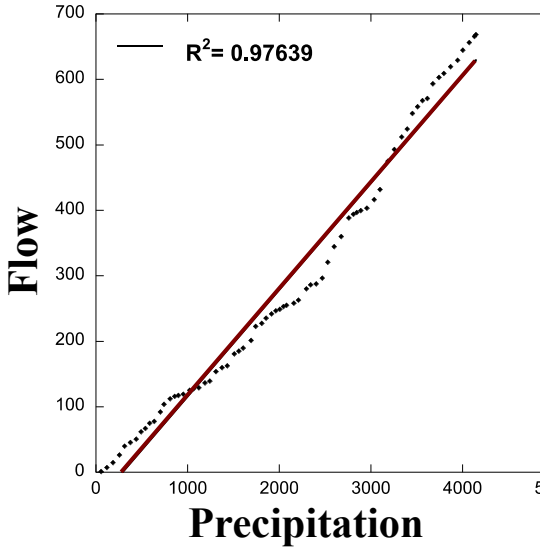


- Underground
- Extensive
- Increasing

Artificial Drainage: Blue Earth County

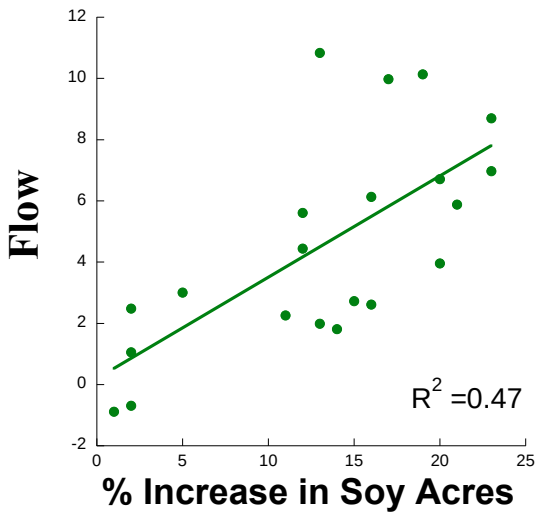
What has changed: 1940-1975 vs 1976-2009

Precipitation



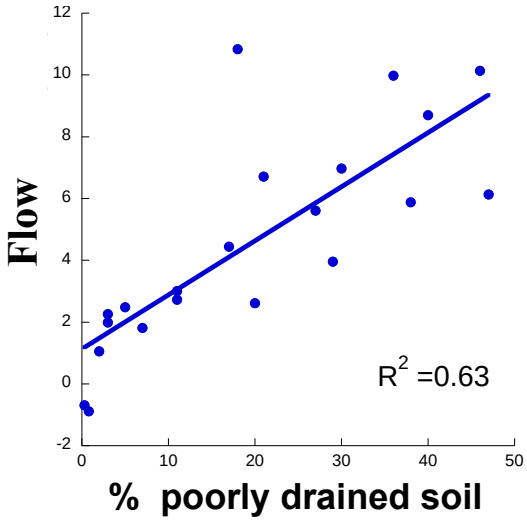
Yes: Correlated to flow increase

Cropping Patterns
increase in soy,
loss of hay, pasture



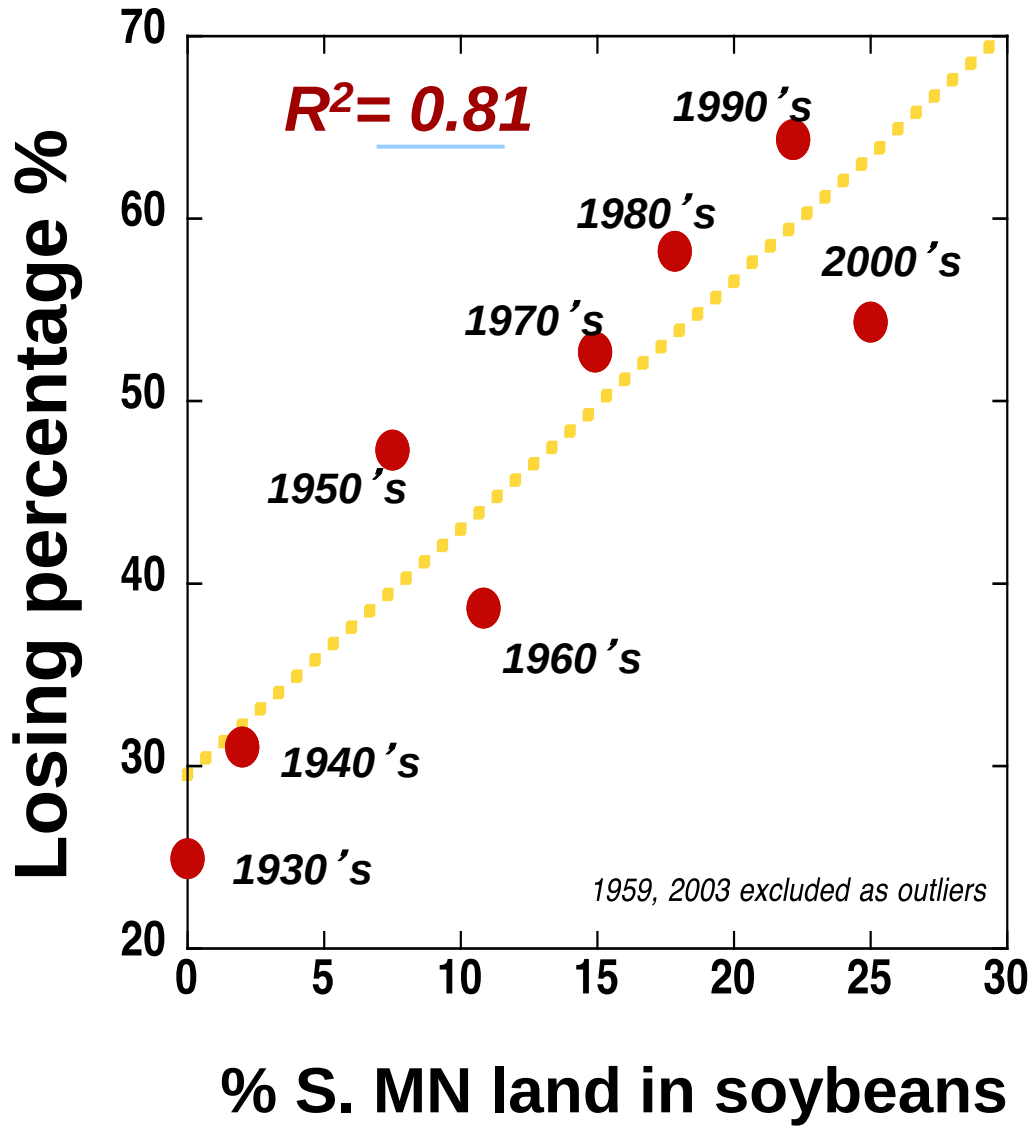
Yes: Correlated to flow increase

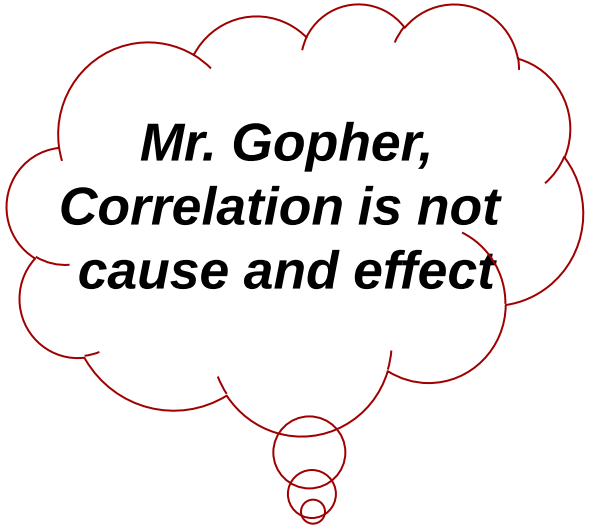
Artificial Drainage



Yes: Correlated to flow increase

Effect of Soybeans on Gopher Football





Lots of things are correlated….

Changes in Precip, Crop conversion and Drainage Installation are Coincident

How do we apportion changes in flow between
- climate, precipitation
- crop conversion
- drainage

Need Math

Precipitation is only half of the story…!

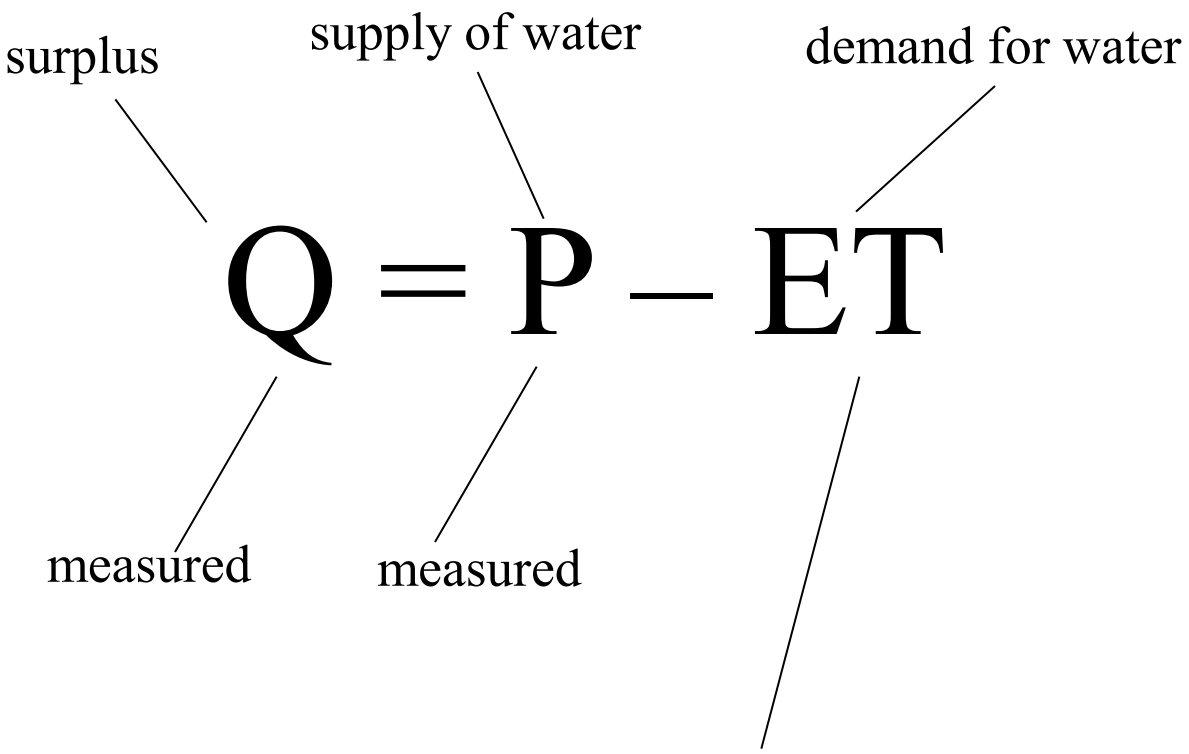
Evaporation and Transpiration

Crop Conversion
and
Artificial Drainage

Can change ET

…the invisible process of disappearing water

Over the long term, water budget simplifies to…



Function of temp, solar radiation, crop type, residence time and precip

Can't solve for by difference because: **ET is not just one thing**

Changes as temp and precip change

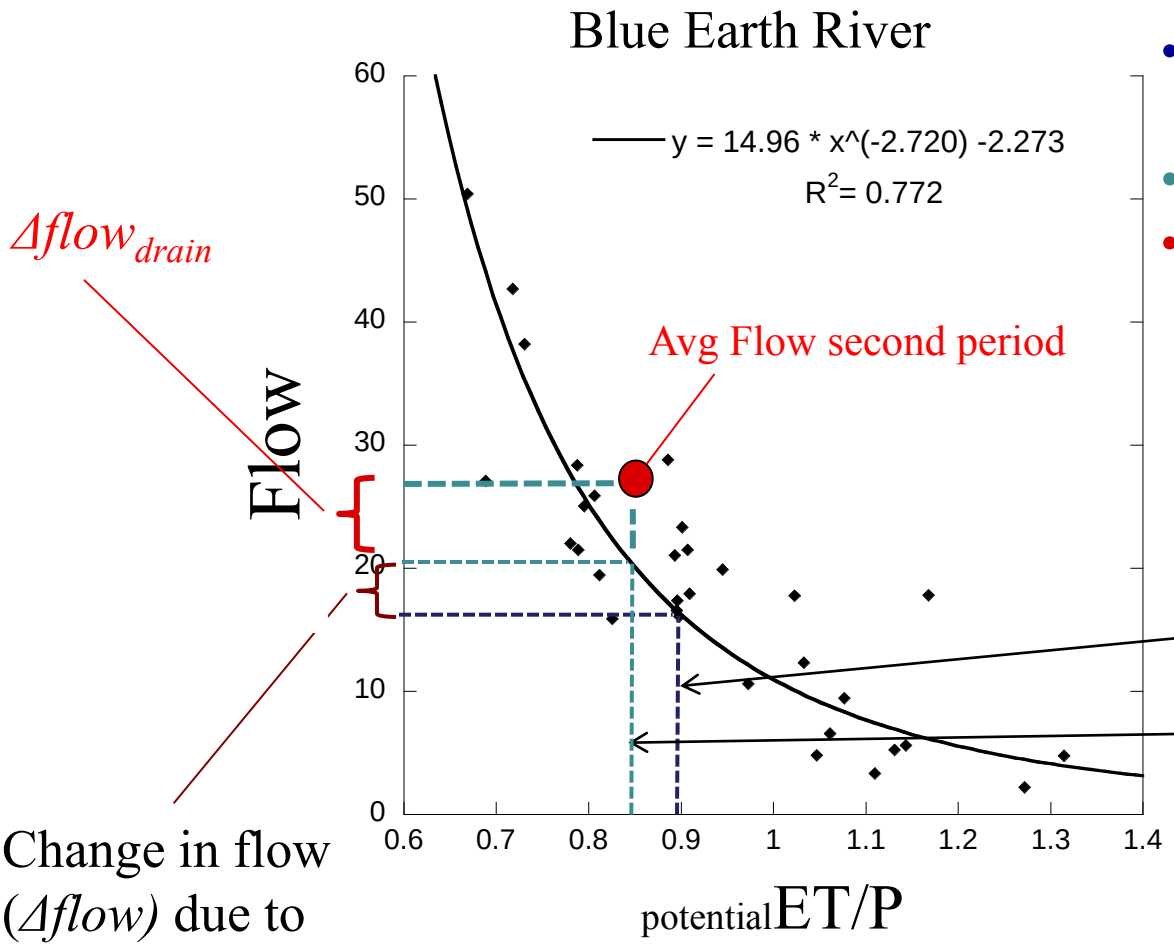
Changes with crop conversion

$$Q = P - ET_{climate} - ET_{crop} - ET_{other}$$

Changes not captured by climate and crop
- water residence time on landscape,
- incremental, on-going changes in storage

Changes due to artificial drainage

Solve by looking at long-term, non-linear relationship of flow to: precip, climate, crop…



$\Delta flow_{drain}$

Avg Flow second period

Change in flow ($\Delta flow$) due to climate and crop

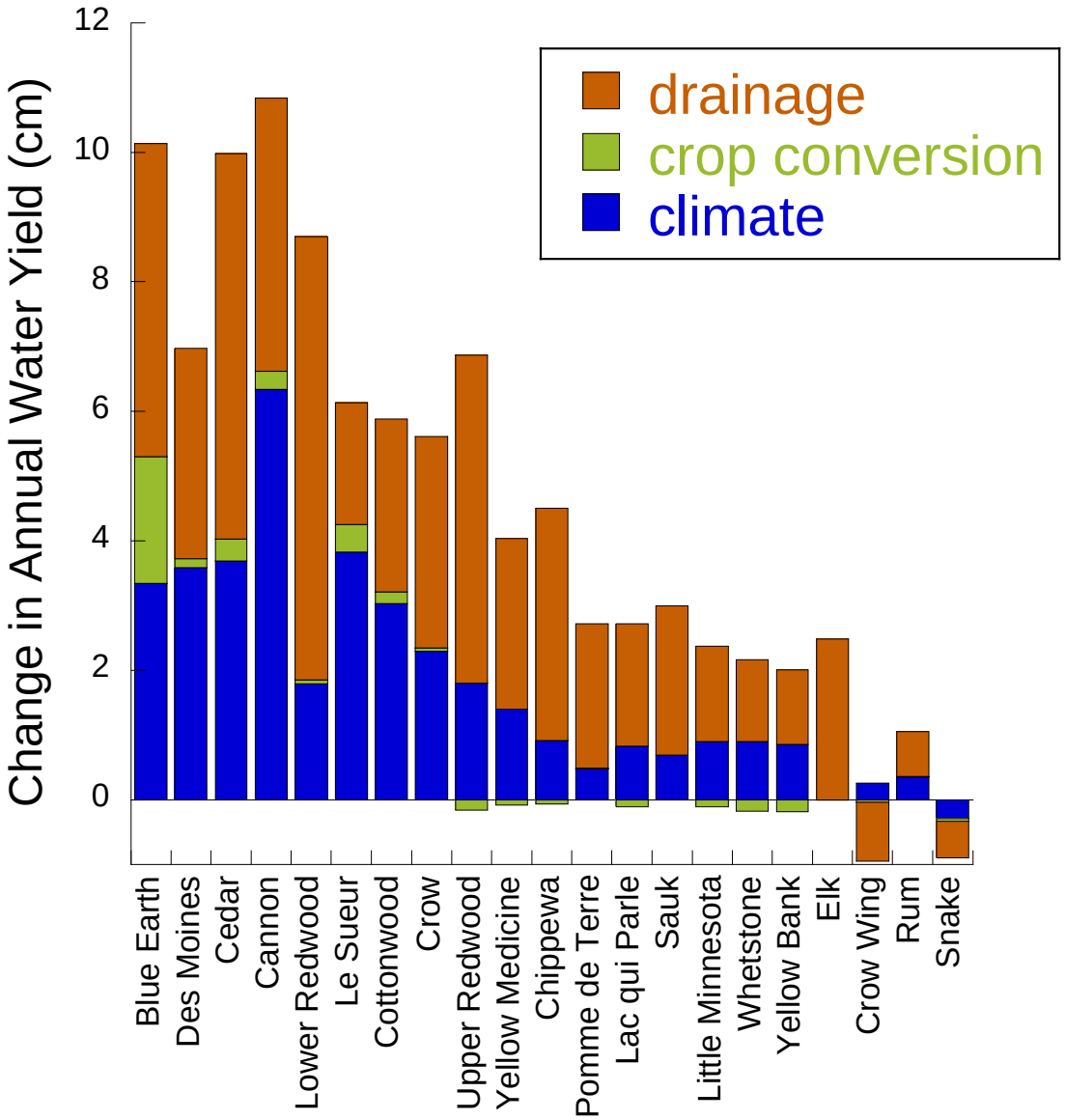
- Calibrate Flow to ET & Precip in first period,
- To predict second period
- Difference is $\Delta flow_{drain}$

Avg. pET/P

1940-1975

1976-2009

Drivers of Changes in Flow for 21 Watersheds



~1/3 of change due changes in precip, or crop conversion

>50 % of change due artificial drainage

Artificial Drainage is a significant driver of changes in flow

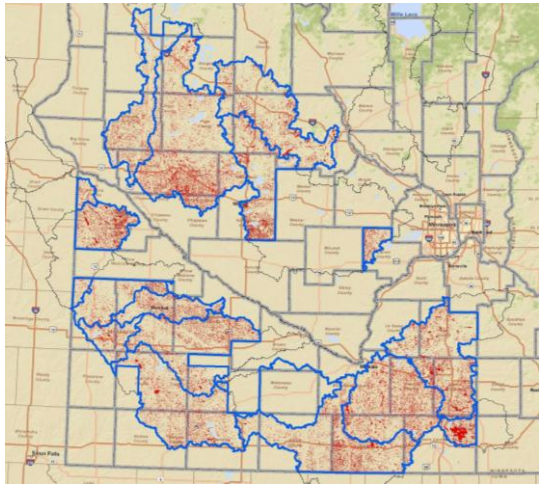
It's all about Residence Time

Artificial drainage reduces water residence time—thus decreasing time for ET—more water available to river.

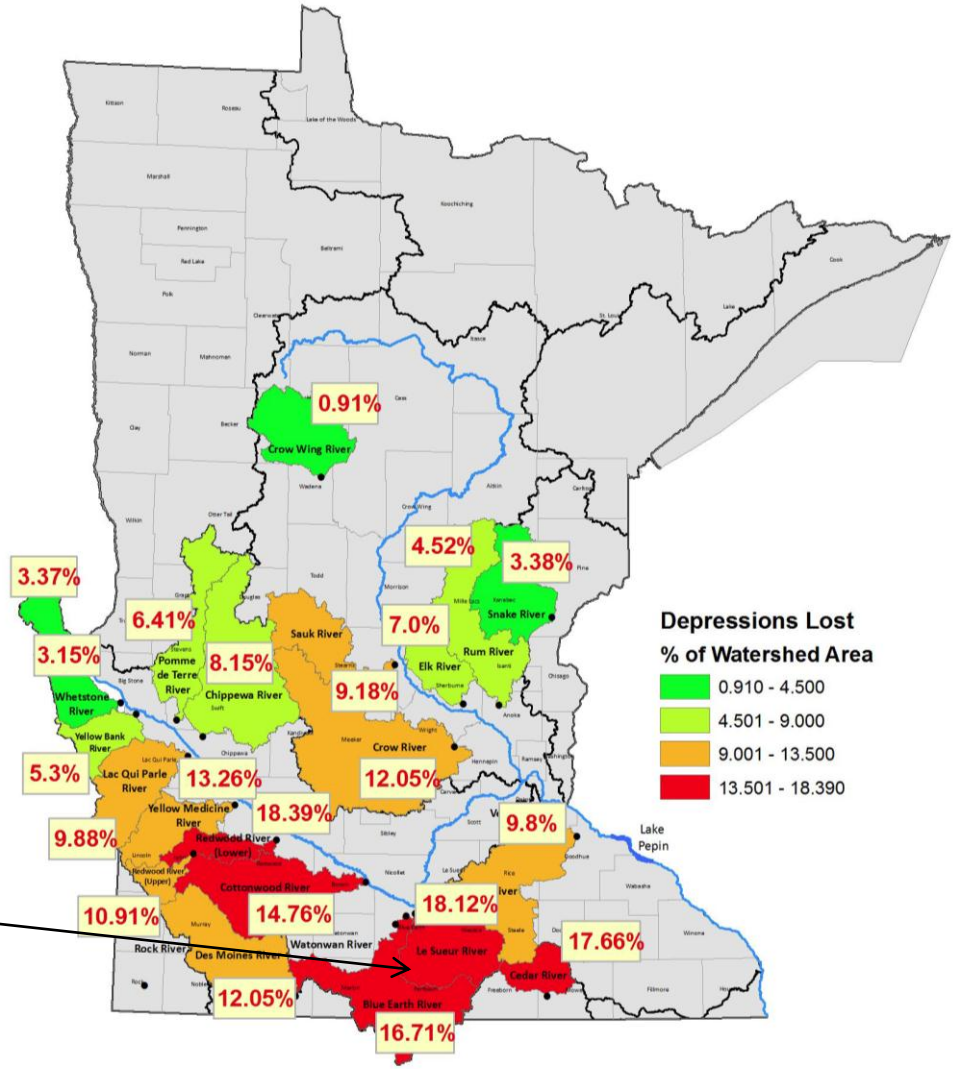
Water that used to evaporate is now routed to rivers

Estimating Loss of Depressional Area

Inventory of drained areas—
USFWS data from infrared air photos



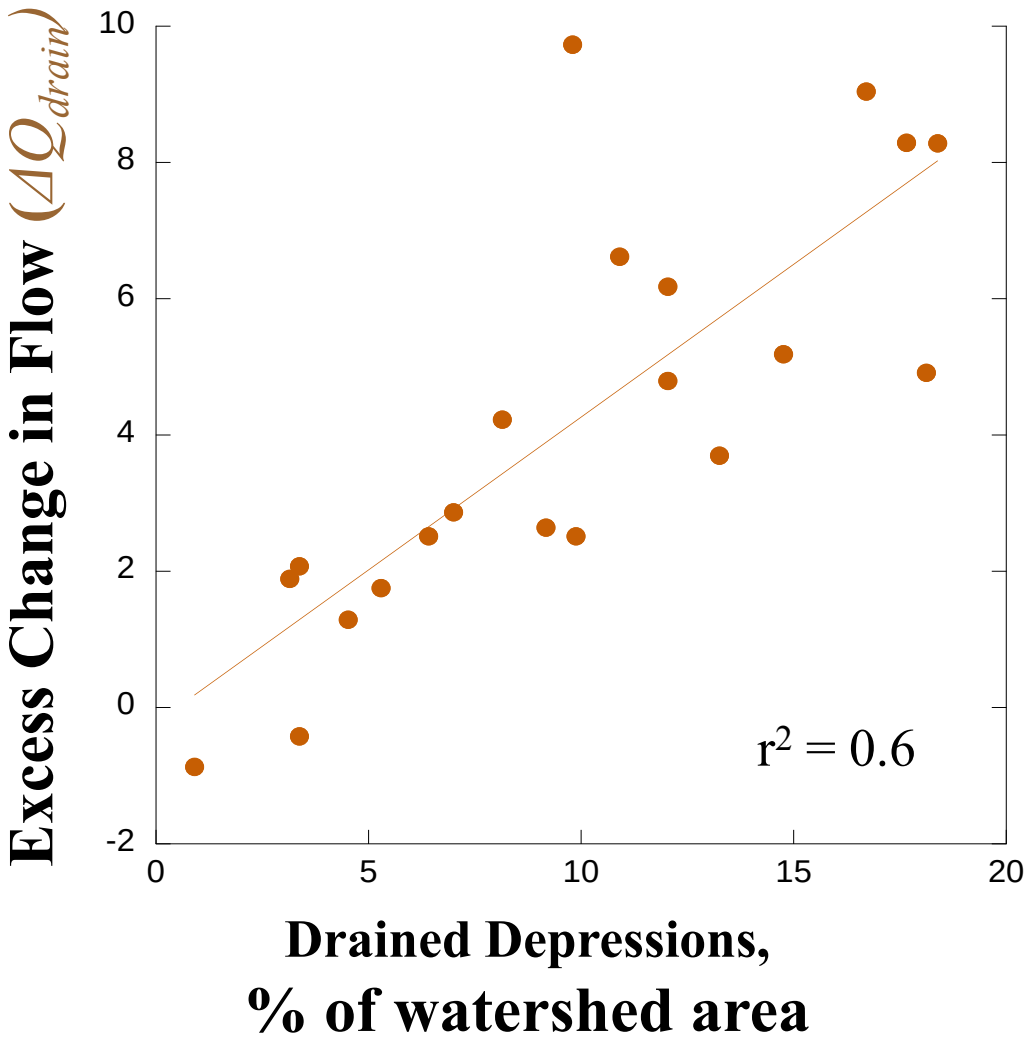
Drained Wetland/Depression

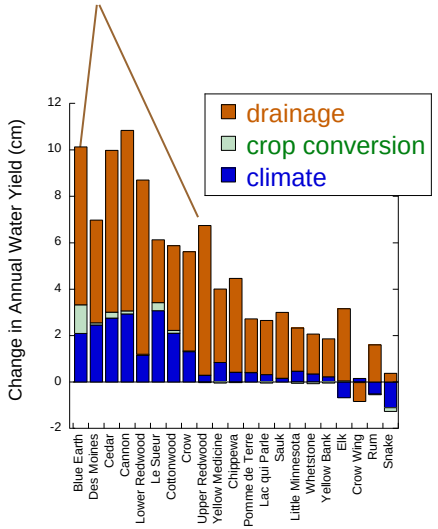


Water storage <u>time</u> on 12-18% of the total land area has been greatly reduced!

Data from Rick Moore, MSU

Supporting Evidence: Does change in flow correlate to loss of depressional area?





- Increase in flow linked to loss of depressions

- Supports Conclusion that..

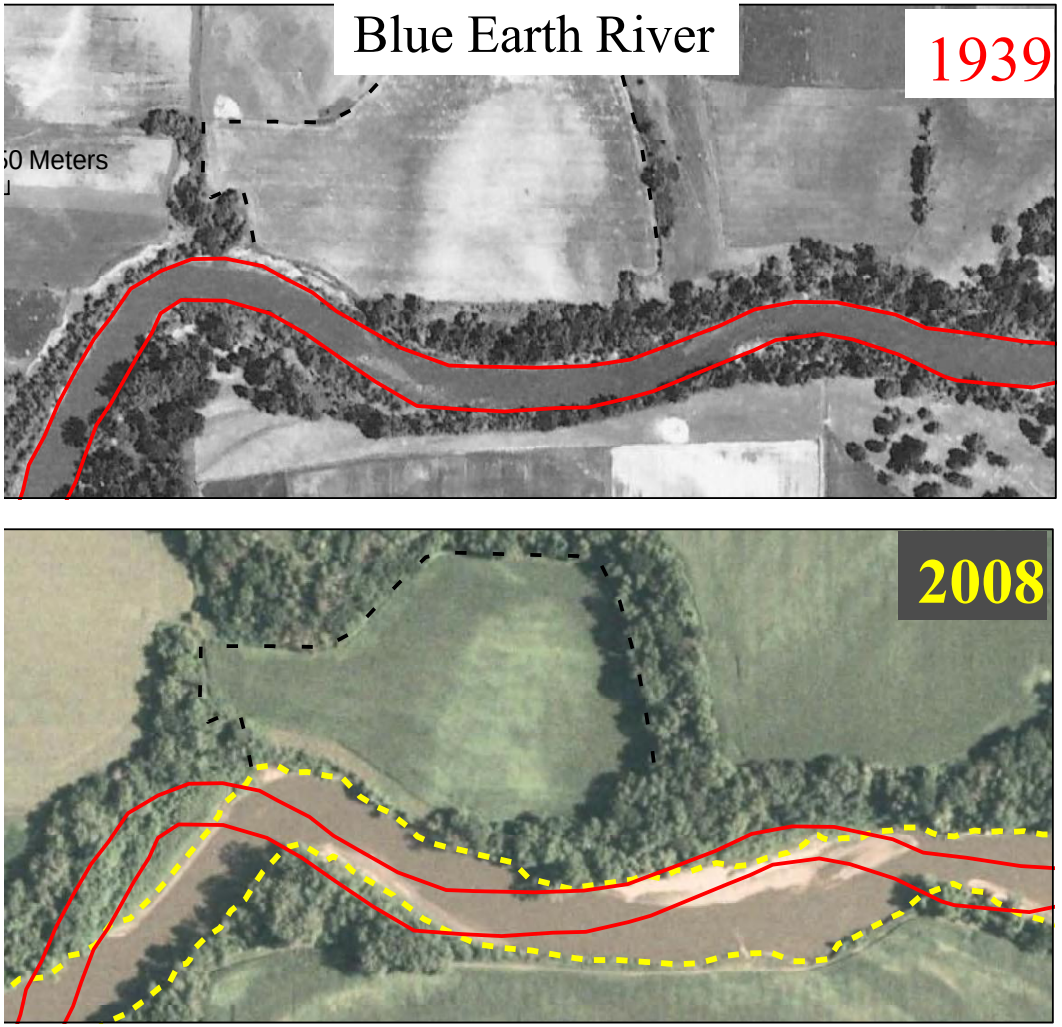
Artificial Drainage accounts for a majority of changes in flow

Consequences

Increased flow causing river channels to widen.

Blue Earth, LeSueur and Minnesota Rivers 15-40% wider

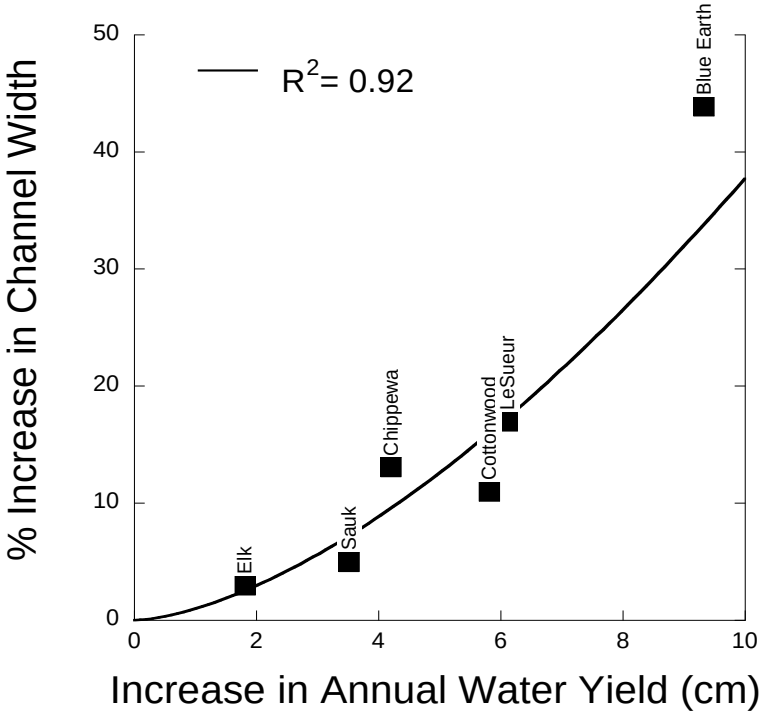
Widening is source of non-field sediment



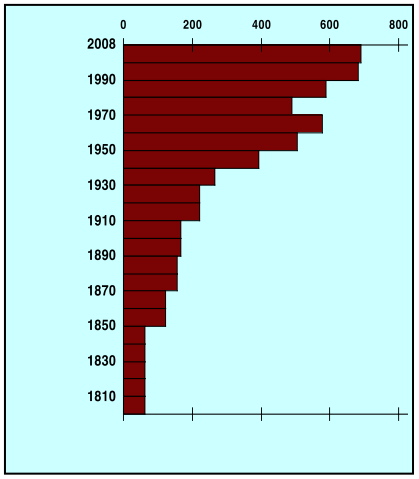
From P. Belmont and W. Lauer

Consequences

Drainage increase flow—channel widening

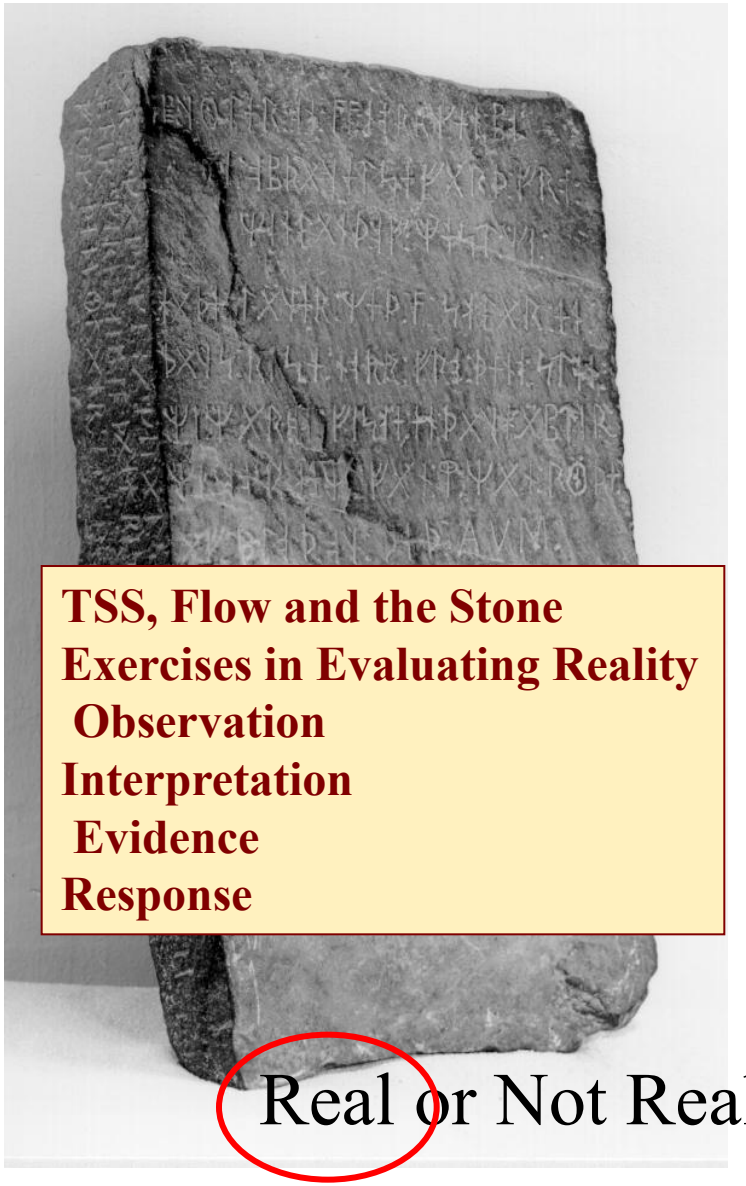


Recall Lake Pepin,
(history of watershed erosion rates)
Non-field loading increased by 5X



Artificial Drainage is an important driver of watershed scale changes to sediment loading--turbidity

Evaluating Reality



TSS, Flow and the Stone
Exercises in Evaluating Reality
Observation
Interpretation
Evidence
Response

Real or Not Real ?

Stone = Real
Runic carvings = Real

Who carved them = interpretation

Vikings explorers vs. Olof Ohlman

Evidence favors Olof

Flow increase = Real, measured
Sediment increase = Real, measured

Cause of increases = interpretation

Climate vs. Drainage vs other

Evidence says >50% drainage

Interpretation Supported by Solid Evidence

There will be a
Response to the Interpretation

Drainage changes water residence time

Which decreases ET losses

Increasing streamflow

Making rivers more erosive

Increasing non-field suspended sediment loads

Management needs to be based on reality,
science needs to describe reality